Dropping balls through fluids

Overview
As children, you probably dropped a rock from a bridge, a penny from a tower, or a water balloon from a window. You may have made the observation that whatever you dropped eventually reached some terminal velocity. You probably also observed the splash your rock made when it the surface of the water below. In this project you will study these seemingly simple phenomena and attempt to understand how a ball falls through liquid, why it achieves terminal velocity, how it interacts with a surface, and what role the properties of the fluid play.

Basic Questions
The central question of this project may be stated as follows: Imagine you are given a column of fluid with height $h$, a sphere of known mass and radius, and are asked to drop the sphere from any height you wish in such a way that it reaches the bottom of the fluid column in the least time possible. From what height should you drop your sphere? A moment’s reflection will reveal the numerous effects and complications you must consider. For example:

1. How do you compute the drag on a sphere? How does the fluid affect the results?
2. What happens when the sphere impacts the surface of a fluid? How much energy is lost at impact? What happens to the surface? To the sphere?
3. How does the container effect the travel time? What happens if the container radius becomes comparable to the sphere’s radius?
4. How does the rheology of the fluids involved affect travel time?

It is expected that you will uncover, define, and investigate questions like these during your work on this project. Some directions will be suggested by the challenges below, while others will arise from your own interests.

Challenges
This semester, several teams will be working on the ball drop project. In addition to your project report and associated milestones, there will be a series of competitions between your team and the other ball drop teams. The four competitions are outlined below.

1. **Week of October 3** - The first challenge is a predictive challenge. I will provide the teams with a column of fluid and a sphere. For this exercise, we will use a Newtonian fluid. The sphere will be placed *within the fluid* and released. The travel time for the sphere to reach the bottom of the container will be measured several times and a mean computed. Prior to any experiments, your team must predict the travel time. Teams will be ranked and scored according to the accuracy of their predictions.

2. **Week of October 24** - The second challenge is also predictive. This time, you will be provided with a column containing *two* fluids. The densities of the fluids will be fairly close. (Think oil and water.) A sphere will be placed within the top fluid and released. The travel time for the sphere to reach the bottom of the container will be measured several times and a mean computed. Prior to any experiments, your team must predict the travel time. Teams will be ranked and scored according to the accuracy of their predictions.

3. **Week of November 14** - The third challenge is also predictive. This time, you will be provided with a column containing *two* fluids. The densities of the fluids will *not* be fairly close. (Think air and water.) A sphere will be placed within the top fluid and released. The travel time for the sphere to reach the bottom of the container will be measured several times and a mean computed.
Prior to any experiments, your team must predict the travel time. Teams will be ranked and scored according to the accuracy of their predictions.

4. **Week of December 5** - The final challenge has two parts. In the first part, you will return to the travel time problem from the first challenge, except the radius of the ball will be comparable to that of the column. The second part is a two fluid problem. You will be given a column of two fluids (one may be air), your goal is to drop the ball in such a way that it reaches the bottom of the column as quickly as possible. You may drop it from any height *above* the interface between the two fluids. As usual, teams will be judged on the accuracy of their theoretical predictions relative to experiment.

**Experiments**

You have full access to the MEC Lab and associated resources to perform any experiments with ball dropping that you wish. Of particular use will be the fluids and balls you will find in the lab, photogates and associated software, and our video, still, and high speed cameras. As you read the literature on the ball dropping problem you should keep in mind experiments that others have carried out and new experiments that are suggested.

**The Literature**

There are various aspects to this problem, each of which has its own literature. Three good books on basic fluid dynamics are (Batchelor 1967; Lamb 1993; Landau and Lifshitz 2000). These books will all discuss computations involving drag. The interface interaction problem has a long history. A good place to start is (Richardson 1948). In (Abaid, Adalsteinsson et al. 2004) you will see that much about interface dynamics is still unknown.


